THE
USE of a NEW
ORRERY,

MADE *and* DESCRIBED

BY

JAMES FERGUSON.

LONDON.

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ADVERTISEMENT.

The following SCHEMES are done, and publish'd,
by *James Ferguson.*

1 THE ASTRONOMICAL ROTULA, shewing
the Place of the Sun, Moon and Moon's
Nodes in the Ecliptic, with their Distances from
one another, every Day in the Year. The true
Times of all the Eclipses of the Sun and Moon, from
1730 to 1800 inclusive; together with the Figures
of all those that are visible, at *London, Edin-
burgh* and *Paris.* The Motions, Magnitudes, solar
Distances, hourly Velocities &c. of all the Planets.
Plain and easy astronomical Tables, never before
published, for calculating the true Time of New
and Full Moon. The Hour of the Day or Night,
in most remarkable Places of the Earth, having
the Time at any one of them given; with several
other Problems; as shown by a printed Directi-
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PATH IN THE HEAVENS, shewing that her pro-
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outside thereof. *Price one Shilling and six Pence.*

3 A PROJECTION OF THE SUN'S ECLIPSE,
as it will happen on the 14*th* of *July* 1748, in the
Forenoon, at *London, Edinburgh* and *Rome. Price
one Shilling.*

PREFACE.

AS the name Orrery is very improperly applied to this Machine, it is necessary to inform the Reader why it has been so called.

Some think it was invented by The Earl of Orrery, but that is a Mistake; for He neither was, nor wanted to be taken for the Inventer of it.

Planetary Machines were made long before his Time, witness the famous Glass Sphere of Archimedes, mentioned by Cicero, who saith, That it shewed the Motions of the Sun, Moon and Planets. Pliny tells us, That Atlas and Anaximander both made such a Sphere; as Diogenes Laertius saith, Musæus also did. Mr. Huygens in his Opuscula Posthuma, gives a Draught and Description of a Machine Invented by himself; wherein all the Planets belonging to our System, are represented going about the Sun, by Clock-Work in their proper Times; but without any of their diurnal Motions, or Inclinations of their Axes. Another Machine was contrived on the same Principles, by Mr. Roëmer.

To represent, in a Machine, the Parallelism of the Earth's inclined Axis, and its diurnal Motion thereon, thro' its whole annual Course; shewing thereby all the beautiful Variety of Seasons, with the different lengths of Days and Nights; must have been look'd upon in any Age, as an Invention worthy of the best Mechanical Genius; but the Honour of such, was reserved for a Gentleman of the present Age; who, above thirty Years ago, made a small Machine, wherein this surprising Motion was represented; I call it surprising, because it shews how

from

from so few Causes, such a variety of useful and wonderful Effects proceed.

The way I have represented Venus *in my Machine, as described in the following Sheets, adds to the Variety of these Effects; tho' I will not presume to say that I could have given such a Representation of her Motion, if I had not been first led into it, by observing the Movement, which in this Machine, carries the Earth round the Sun in the Parallelism of its Axis; for all the Difference betwixt the Motions of these two Planets consists in this, that* Venus's *Axis is more inclin'd than the Earth's; that her diurnal Motion thereon is slower; and her annual Motion quicker than the Earth's; and hence arise a Multitude of different Appearances.*

The beautiful Simplicity of the diurnal and annual Motions of the Earth on its inclin'd Axis, having been Mechanically represented by the above said curious Gentleman; made others desirous to imitate the same in Planetary Machines; and I am told that Mr Rowley *was the first who succeeded therein; and having finished his Machine, he called it the* HORARY; *perhaps from its shewing the hourly Motions of the Planets: But upon the* Earl of Orrery's *buying it from him, he called it the* ORRERY. *I have heard other Accounts of it, but this seems to be the most probable.*

Any Machine of this sort ought to be called by some Name analogous to what it represents; such as, The Celestial Atlas; The Copernican Sphere; *or as* Dr. Desaguliers *very justly terms it,* The Planetarium. *But as it has been for above thirty Years called* The Orrery, *I let my Planetary Machine pass under that Designation; because when Names are changed, Things are seldom so well known.*

THE

DESCRIPTION and USE

OF THE

ORRERY.

THIS Astronomical Machine shews the Motions of the Sun, Mercury, Venus, Earth and Moon; with the retrograde Motion of the Moon's Nodes, and the Phænomena of the Tides. The Reason why I put none of the superior Planets in it, is, because there can be no Regard had to their proportional Magnitudes and Distances, without crowding the Earth and inferior Planets so near to one another, and making them so small, that their diurnal Motions, and the Appearances arising from them, could not be shown so as to be useful either for Instruction or Amusement; even tho' the Movement was four or five Feet in Diameter: But where it is only eighteen Inches, the Earth and the inferior Planets may be put at their proportional Distances from the Sun, so as to shew their true Phænomena depending on their Distances. Indeed the Magni-

tudes

tudes, with respect to the Distances, cannot be represented; but with respect to one another, they may; and without interfering with one another, they may be made large enough to shew the Effects both of their diurnal and annual Motions. When large Orreries shew all the Planets, little is to be observed in Mars's Motion; and as for the System of Jupiter, that can be much better represented in a Machine by it self, where the Satellites move at their proper Distances from Jupiter, as measured by his Semi-diameters; and such a Machine can be made to shew the Eclipses of these Satellites for a long Time by Clock-work, very near to the Times that they happen in the Heavens: Besides, the fewer Wheels and Friction there is in any Machine, the less liable it is to be out of Order.

Jupiter's System better shown by itself.

IN this ORRERY, the Sun is placed nearly in the Center; supported by a Wire or Axis, round which it turns in twenty five Days and an half. Its Center always keeps in the Plane of the Ecliptic, or large broad Ring, whereon the Months and Days, with the Signs and Degrees are engrav'd, so as every Day may stand over the Place of the Ecliptic, in which the Sun *is*, on that Day. This is adapted to the second Year after Leap Year, because it is the nearest for finding the Sun's Place, when there is but only one Circle of Months and one of Signs, to serve for every Year. This Ring, or flat broad Circle, is supported by twelve Pillars; and has an annual Index or Pointer moving over it, and keeping always in the same strait Line with the Sun and Earth; whereby it shews the Sun's apparent Place in the Ecliptic, as seen from the Earth, every Day in the Year. The Sun's Axis makes an Angle of $82\frac{1}{2}$ Degrees with the Plane

See the Figure fronting the Title Page. The Sun always in the Plane of the Ecliptic. The Sun's Place.

His Axis inclin'd to the Ecliptic.

Plane of the Ecliptic, still keeping the same Position; but will be varioufly inclin'd to the Earth, fometimes leaning toward it; at other Times fidewife to it, and then from it; this is occafioned by the Earth's going round the Sun: And when the Sun's North Pole inclines toward the Earth, his Spots will feem to move over his Difc, in a Curve bending downwards; when it inclines from the Earth, the Curve they defcribe, will bend upwards, and when his Axis, inclines fidewife to the Earth, the Spots will appear to move in a ftrait Line. *Motion of his Spots.*

NEXT to the Sun is a fmall Globe reprefenting *Mercury*, whofe annual Motion round the Sun is performed in eighty feven Days and twenty three Hours; but has no Motion on his Axis in the Orrery; becaufe the Time of his diurnal Motion in the Heavens is not yet known: Tho' 'tis very probable that he turns round his Axis as the reft of the Planets do; on Account of the great Conveniency arifing from the regular fucceffion of Day and Night. *Mercury.*

THE next Planet in order is *Venus*, which is ufually reprefented in Machines of this kind, as having her Axis perpendicular to the Ecliptic, and her diurnal Motion equal to twenty three Hours of our Time, according to *Caffini's* Obfervations; whereby her Year contains nearly two Hundred and Thirty five of her Days, equal to two Hundred and twenty four Days; and feventeen Hours on our terreftrial Globe. If this be true, *Venus* can have no Variation of Seafons; and fo her annual Motion can be of no other Ufe than to prevent her falling into the Sun. But by *Bianchini's* Obfervations, it is far otherwife; for he fays, that her Axis inclines feventy five Degrees from the Perpen- *Venus.*

Bianchini's Account of her.

Perpendicular to the Plane of the Ecliptic, and her diurnal Motion is performed in twenty four Days and eight Hours of our Time; her North Pole inclines toward the twentieth Degree of *Aquarius*, and her Axis always keeps parallel to it felf, thro' her whole annual Course, which he owns to be performed in the fame Time (with Refpect to our Earth) as *Caffini* favs it is.

On Account of *Bianchini*'s great Candour, and the Satisfaction He gave to fome Perfons of Diftinction, who being very well fkill'd in Aftronomy, were prefent with him, at making his Obfervations, 'tis highly probable that he was not miftaken; and therefore I have made *Venus* in my Orrery move fo, as may exactly agree with his Obfervations; by which fhe has the following remarkable Affections.

Suppos'd to be the beft.

1. Her Axis is inclin'd fifty one Degrees and a half more than the Axis of our Earth, and therefore her Variation of Seafons muft be much greater than ours.

2. The Sun's greateft Declination on each Side of her Equator, amounts to feventy five Degrees; therefore her Tropics are only fifteen Degrees from her Poles; and her Polar Circles at the fame Diftance from her Equator: Confequently, her Tropics are between her Polar Circles and Poles; contrary to what thofe on our Earth are.

3. Her annual Revolution contains only 9¼ of her Days equal to two Hundred and twenty four Days and feventeen Hours of our terreftrial Time: Hence the Sun will appear to go thro' every Sign of the Zodiac, in eighteen and near one eighth of our Days; which make little more than three quarters of a Day in *Venus*.

4. Because

4. BECAUSE her North Pole inclines toward *Aquarius*, her Northern Parts will have Summer in the Signs where those of our Earth have Winter; and *vice versâ*.

5. THE artificial Day at each of her Poles, will be equal to 112 ½ natural Days, on any Part of our Earth, from the Equator to the Polar Circles.

6. BECAUSE her Day is so great a Part of her Year, the Sun changes his Declination every Day, 32 ½ Degrees; which is nine Degrees more than it changes in a quarter of a Year on our Earth. This seems to be Providentially ordered for preventing the too great Effect of the Sun's Heat (which is twice as great on *Venus* as on our Earth) by hindering the Sun from shining perpendicularly over the same Countries for two Days together; and by this Means, the heated Places have Time to cool.

7. THE Distance of the Spirals of the Sun's Declination, in every apparent Circumvolution round *Venus*, may be found thus: Suppose an Inhabitant at her North Pole, viewing the Sun, and a graduated Semi-circle, so placed as to touch the Horizon in two opposite Points, and to pass thro' the Zenith and the Sun, when he is at his greatest Declination, or at the highest; let the Spectator keep his Face toward that Side of the Semicircle, and he will have the following Phænomena.

THE Sun will rise about one hundred and twelve Degrees to the left Hand of the Semi-circle, and ascending gradually, he will cross it at an Altitude of ten Degrees; then making an entire Revolution, he will next cross it again at an Altitude of 42 ½ Degrees: At the next Revolution he will cross it as he Culminates, at an Altitude of seventy

ty five Degrees, being then only fifteen Degrees from the Zenith ; whence he will defcend in the fame fpiral Manner, till he fets about one hundred and twelve Degrees to the Right Hand of the Semi-circle; from which Place he defcends below the Horizon, to exhibit the like Phænomena at the South Pole.

8. At her Equator, the Days and Nights will not be equally long all the Year; becaufe the Sun changes his Declination fo much every Day ; and when it is at the greateft on either fide of the Equator, the Sun will then be only fifteen Degrees from the Zenith of the neareft Pole ; both Poles lying in the Horizon of all Places on the Equator. Therefore the diurnal and nocturnal Arches muft be very unequal about that Time: For, fuppofe to a Place on the Equator, the Sun *The Days* comes to his greateft Declination at Mid-night, *andNights* he will then be only fifteen Degrees below the *not equal-* Horizon ; whereas at the Mid-day either foregoing *ly long* or following, his Declination being $16\frac{1}{4}$ *under the* Degrees lefs, his meridian Altitude will be *Equator.* $31\frac{1}{4}$ Degrees; which is $16\frac{1}{4}$ more than his Mid-night Depreflion; and therefore the Day will at leaft be twice as long as the Night. To any Place where the Declination is greateft at Mid-day, the Effect will be contrary. As the Sun returns from either of the Tropics toward the Equator, the Days and Nights approach nearer to an Equality; and to the Place where the Sun paffes over the Equator at Noon, that Day is Equal in length to its Night.

9. From the great change of the Sun's Declination every Day, it will happen, that when he rifes in the Eaft, he will not on that Day fet in the Weft, as with us ; but about North Weft by Weft ; and when he rifes South-Eaft by Eaft, he
will

will on that Day set about the Weft. Becaufe the ri-
fing and fetting Amplitude of the fame Day is al-
ways fo different, the Foorenoon and Afternoon
can never be of an equal Length, fave only at
the Poles ; and on the Equator, where the Sun
croffes it at Noon ; for at all other Places, the
Sun is every Day nearer to, or further from the
Meridian when he rifes than when he fets, by a
Quantity equal to the Difference of his Ampli-
tude at rifing and fetting.

The Fore-noon and Afternoon never equally long fave under the Poles.

10. At *Venus's* Equator, the Sun's Rays will
be as oblique when his Declination is greateft, as
they are at *London* when he touches the Tropic
of *Capricorn* in *December* ; becaufe her Tropics
are as far from her Equator on each Side thereof,
as the Tropic of *Capricorn* is from the Parallel of
London on our terreftrial Globe. Therefore at
her Equator, there will be two Winters, two
Springs, two Summers and two Autumns every
Year: And, becaufe the Sun ftays for a confider-
able Time about the Tropics, and paffes fo
quickly over the Equator, every Winter there will
at leaft be twice as long as Summer. But the
Winters will be tolerably mild ; becaufe (as was
faid above) the Day will be fometimes twice as
long as the Night ; and then the Obliquity of the
folar Rays will be much compenfated by their
duration: Where the Reverfe happens, with regard
to Day and Night, the Odds cannot be fo great as
in *Britain*; becaufe the different Lengths of Day
and Night are not comparatively fo great at the
Equator of *Venus*.

The four Seafons twice eve-ry Year at the Equa-tor.

11. At her Poles, there is but one Day and one
Night in the whole Year: There, the Difference
between the Heat in Summer and Cold in Winter
(or of Mid-day and Mid-night) is greater than
betwixt the fame in any two Places on our

Earth ,

Earth: Becaufe in *Venus*, the Sun is for half a Year together above the Horizon of each Pole, in its turn; and for a confiderable Part of that Time near the Zenith: And during the other half of the Year, always below the Horizon, and for a great Part of that Time about feventy Degrees from it. Whereas at the Poles of our Earth, tho' the Sun is for half a Year together above the Horizon, yet his Altitude is never twenty four Degrees above it in Summer, nor his Depreffion greater than that Quantity below it in Winter: When the Sun is in the Equator, he will be feen in the Horizon of both Poles; one half of his Difc above, and the other below: And defcending quite below the Horizon of one, will afcend gradually above that of the other; going round in a fpiral Manner as he afcends, until he comes within fixteen Degrees of the Zenith, where he keeps the fame Altitude nearly for fome Time; then defcends in the like fpiral Manner, till he has got below *And once at each of the Poles.* the Horizon, where he continues invifible for the other half of the Year. This will occafion to each Pole one Spring, one Harveft, a Summer as long as them both, and one Winter equal in length to the other three Seafons.

12. AT the Tropics, the Sun in Summer will continue for feveral of our Weeks together above the Horizon, without fetting, and as long below it in Winter without rifing. While he is *Phænomena at the Tropics.* more than fifteen Degrees from the Equator, he neither fets to the Inhabitants of the neareft Tropic, nor rifes to thofe of the other; but afcends gradually in a fpiral Line towards the Zenith of the former, till he reaches it; then defcends in the like fpiral Manner towards the Horizon without fetting, till he comes within fifteen **Degrees**

Degrees of the Equator; and then sets to the one Tropic, and rises to the other, in which the Phænomena are the same.

Those Parts of *Venus* which ly betwixt the Poles and Tropics, and between the Tropics and Polar Circles; and also between the Polar Circles and Equator, will more or less participate of the Phænomena of these Circles, as they are more or less distant from them.

13. The Sun's Altitude at Noon, or any other Time of the Day, and his Amplitude at rising or setting, will be very different in Places lying under the same Parallels of Latitude, according to the Difference of Longitude of these Places; because the Sun's Declination varies so much in the Time that *Venus* makes one diurnal Revolution on her Axis.

Different Phænomena in Places of the same Latitude.

14. The Places of the Equinoxes and Solstices on the Body of *Venus* go backward, or from East toward the West, ninety Degrees every Year: This is occasioned by the Sun's being a quarter of a Day later every Year in crossing the Equator, than on the Year before; and therefore he will cross it in a Place ninety Degrees Westward of the former, every Year. Hence, tho' the Spiral in which the Sun's apparent Motion is performed, be of the same sort every Year, yet it will not be the very same; because the Sun will not pass vertically over the same Places, till four annual Revolutions are compleated. This will make the Phænomena very different at different Places of the Equator, especially with Regard to the different Lengths of Day and Night in each Winter; which will also be different to each particular Place thereon, from what they were on the preceeding Year; beginning the same Course over again, at the End of every four Years. 15. This

The Equinoxes and Solstices go backward ninety Degrees every Year.

15. THIS great annual Change of the Equinoxes and Solstices in *Venus*, will shift her Seasons forward a quarter of her Day (or about six of ours) every Year ; which in four Years, will amount to a whole Day : And consequently, in eighteen Years, her vernal Equinox and Summer Solstice will fall on the same Days of the same Months, whereon her autumnal Equinox and Winter Solstice fell eighteen Years before : Therefore in thirty six Years her Seasons will shift forward, thro' all the Days of her Year, and then return to the same Days of the same Months they began *A Rectification of Venu's Calendar.* at. Wherefore to rectify *Venus'* Calendar, or to keep always the same Seasons to the same Months and Days, it will be necessary to intercalate a Day every four Years, which will bring her Days to an even Reckoning, by making every fourth Year a Leap Year, containing ten Days ; and her Calendar will need no other Rectification.

THESE are the principal Phænomena arising from the Motions of *Venus*, as they are performed in this Orrery ; and I shall only add an Account of some Appearances that must happen, whether her Axis be perpendicular, or oblique to the Plane of the Ecliptic ; and which do not depend upon the Times wherein either her diurnal or annual Motions are performed.

1. To the Inhabitants of *Venus*, the Sun's *How the Sun and Planets appear to Venus.* Diameter will appear one half greater then it does to us on Earth ; and therefore his Disc, will appear more than twice as large seen from *Venus*, than it does seen from the Earth, her Light and Heat will also be double to ours.

2 THE Phænomena of *Mercury* seen from *Venus*, will be much the same as of *Venus* seen from the Earth ; sometimes Rising before, and

at

at other Times fetting after the Sun ; but he will be oftner seen stationary and retrograde ; never further from the Sun than thirty eight Degrees : he will also feem to increase and decrease as the Moon does.

3. The Inhabitants of *Venus* will fee four superior Planets, whose Phænomena will be much like those of *Mars, Jupiter* and *Saturn* seen from the Earth; but our Earth will be the moft remarkable of them, when in oppofition to the Sun ; for then it will shine with a full Orb, very bright in the Night, and with a larger Disc than *Venus* has when feen from the Earth ; after which it will gradually diminish both in its Luftre and Figure, until toward the Conjunction ; when it will hardly be diftinguishable by the naked Eye from a fixt Star. The Moon will appear to accompany the Earth (as *Jupiter's* Satellites do *Jupiter*) to throw her Shadow upon it, and be Eclipfed by it.

NEXT to *Venus* is the Earth, with its Satellite the Moon, which goes round the Earth in twenty feven Days and eight Hours, thro' all the Degrees of her Orbit ; or from any given fixt Star to it again : This is called the Moon's periodical Revolution. But from the Sun to the Sun again, or from any particular New Moon to the next, she takes twenty nine Days and an half; which is called her fynodical Revolution. In accompanying the Earth, she is carried with it, round about the Sun once every Year. *The Earth and Moon.*

Both go once round the Sun in a Year.

ON this *Terella*, or little Earth, is delineated a fmall sketch of a Map, with the Equator, Tropics, Polar Circles and fome Meridians ; whereof two reprefenting the Colures crofs one another at right Angles in the uppermoft, or North Pole, and

and in the lowermoft, or South Pole. The Wire-
pafing thro' thefe Poles, whereon the Earth turns
round, is called the Earth's Axis; which inclines
Inclina- 23½ Degrees from the Perpendicular to the
tion of the Plane of the Ecliptic : The North Pole con-
Earth's ftantly leans toward the beginning of *Cancer*,
Axis. for theEarth thro' its whole annual Courfe keeps
its Axis Parallel to it felf: That is, if in any
Part of the Earth's annual Path, a Line be
Its Para- drawn parallel to her Axis, it will always
lellifm. be Parallel to that Line.
what ?

THE Earth in each Rotation on its Axis, from
any fixt Star to the fame again, meafures a fyde-
Sydereal, real Day, or 23 Hours, 56 Minutes, and 4 Se-
and Solar conds, of mean folar Time, but from the Sun to
Days. the Sun again, juft 24 Hours of the fame Time,
according to a mean Motion.

UNDER the Earth is a fmall Dial Plate di-
Sydereal vided into 24 equal Parts, which are the fyde-
Hours. real Hours : An Index fixt on the Earth's Axe,
moves round this Plate every fydereal Day; and
becaufe the Plate always keeps parallel to it felf,
the fame Hours always point toward the fame
fixt Stars. Its Index fhews the fydereal Hours ;
and the difference of Time between the Sun's
coming to the Meridian of any Place, and of any
given fixt Star's coming to the faid Meridian,
every Day in the Year.

ON the Cover of theMachine are twoCircles, one
whereof is divided into 29½ equal Parts,
Moon's which are the Days of the Moon's Age,
Age. as pointed out by its Index, while the Moon goes
round the Earth : The other Circle is divided
into twice twelve Hours, having an Index to
point out the folar Hours thereon, as the Earth
turns its different Parts toward the Sun : And in
theTime that any particularMeridian Semi-circle
revolves

revolves round from the Sun to the Sun again, the Index of this hour-Circle (as it fhall be always called) will go once round it, over all the twenty four Hours thereon ; fhewing when the Sun rifes and fets, with the difference of Time, at all Places delineated on this fmall Globe or Earth. The Hour-Circle does not keep parallel to it felf, as the fydereal Dial Plate does, but has one of its XIIs always pointing toward the Sun, to reprefent Mid-day; as the other XII pointing the contrary way, denotes Mid-night.

THE fydereal Index always goes 3 Minutes and about 56 Seconds fooner round its Dial Plate, than the Solar Index does round its Hour-Circle, every Day in the Year; and thefe Differences added together, make one turn of the fydereal Index (or of the Earth abfolutely round its Axis) in a Year, more than the number of natural Days contained in the Year. Therefore in 365 Days, the Earth turns 366 times round its Axis, which muft happen, becaufe the diurnal Motion of the Earth round its Axis, and its annual Motion round the Sun, are both performed the fame way, namely from Weft to Eaft; thus, one turn of the Earth with refpect to Day and Night, is loft in the Year; as it would be loft to a Traveller in going round the Earth from Eaft to Weft, following the Sun's apparent diurnal Motion. Hence, if the Earth had no annual Motion, the Sun and fixt Stars would ftill keep the fame Situation with refpect to one another, and then the folar and fydereal Time would always be the fame.

The Sydereal Day always fhorter than the folar Day.

IN Working this Machine, every turn of the Handle anfwers exactly to a natural Day, by caufing any particular meridian-Semicircle

of

of the Earth revolve round from the Sun to the Sun again; and by carrying on the diurnal and annual Motions together, shews a Day's progress of the Planets in their annual Orbs; and what Proportion the length of their Days have to ours at all Times.

ALTHOUGH the Moon in her Orbit sometimes ascends above, and at other times descends below the Plane of the Ecliptic, yet the Earth never deviates from it; for its Plane always passes thro' the Centers of the Earth and Sun; which is the *Why the Sun is always seen in the Ecliptic.* Reason why the Sun always appears in the Ecliptic, as seen from the Earth; and of the Moon's appearing sometimes higher and sometimes lower in the same Signs, than the Sun does therein. Because the Sun remains in the Center of our System, and the Earth has a Progressive Motion in the Ecliptic, when we say, the Sun is in such a Sign or Degree, the meaning of it is, that the Earth is really in the Sign or Degree opposite to the Sun's apparent Place.

THE Parallelism of the Earth inclin'd Axis, as it turns round the same, and its simple Motion *Variation of Seasons.* in the Ecliptic, solves all the Phænomena of Day and Night, with the gradual Increase and Decrease thereof, and all the Variation of Seasons as they continually change. *To make these things the plainer, let us take a view of the Earth once round its annual Orbit.*

TURN the Handle till the Pointer on the Ecliptic comes to the beginning of *Aries* which Sign the Sun apparently enters as seen from the Earth, when it is at the beginning of *Libra*: The Sun is then vertical to the Equator, whose Plane, if produc'd, would pass thro' the Sun's centre, and form the Equinoctial in the Heavens. In this

this Pofition, the Earth is enlightned from Pole to Pole; as is fhown by a black Cap, which covers one half of the Earth, and now with its Edge cuts both Poles. Becaufe this Cap ftill faces the Sun, dividing the enlightned Hemifphere from the darkned One (or the Day from the Night) the Limit of its Edge reprefents *the Circle bounding Light and Darknefs*. To all Places of the Earth coming out from below the weftern Edge of the Cap, the Sun appears to rife in the Eaft; and fets in the Weft, as they go into the Dark, under the eaftern Edge of the Cap. As the Earth turns round its Axis in this Pofition, juft one half of the Equator, and all its Parallels go equally thro' the Light and the Dark, becaufe they are all equally cut by the Circle bounding Light and Darknefs; therefore the Days and Nights are of equal Length, that is twelve Hours each, over all the Earth. This you may farther obferve, by any meridian-Semicircle coming out from below the Cap, when the Index on the Hour-Circle is at Six in the Morning; for then turning the Handle till the Index comes to Six in the Evening, the fame meridian-Semicircle will all at once go in below the Cap; and ftay under it, till the Index comes again to Six in the Morning. The Earth being thus at the beginning of *Libra*, and the Sun as feen from it, at the beginning of *Aries*; makes vernal Equinox to thofe who inhabit the Earth on the north Side of the Equator, and autumnal Equinox to thofe on the fouth Side thereof. The Sun now rifes to the north Pole, which you'll fee conftantly Illuminated; and fets to the fouth Pole, which will be hid in the Dark; till the Sun appears at *Libra*, when the Earth has travell'd half round

The Circle bounding Light and Darknefs.

Equal Day and Night.

Vernal Equinox.

its

its annual Courſe to *Aries* ; that is, half round the Ecliptic.

As the Earth moves from *Libra* toward *Capricorn*, you'll ſee the north Pole gradually coming into the enlightned Hemiſphere, as the ſouth Pole goes from it into that which is in the Dark. The Days now gradually lengthen at all Places on the north Side of the Equator, and the Nights ſhorten in the ſame Proportion, while the contrary happens in the ſouthern Parts, till the Earth comes to the beginning of *Capricorn* ; and the Sun as ſhown by the Pointer, appears at *Cancer*. In this Poſition of the Earth, all the Space included within the arctic Circle, or the whole north frigid Zone, is entirely enlightned ; and the ſouth frigid Zone, or Space bounded by the antarctic Circle is hid in Darkneſs. The Days are now at the longeſt between the Equator and arctic Circle, being gradually longer as the Places are more diſtant from the Equator : But in the ſouthern Hemiſphere, the Effect is contrary ; the Days being there at the ſhorteſt, and Nights at the longeſt. It is now Mid-day at the north Pole to which the Sun roſe, and Mid-night at the ſouth Pole whereto he ſet, when at his entring *Aries*, the Earth was at the beginning of *Libra* : For at each Pole the Day is equal to the Night, which is half a Year long. The Sun being now vertical to the Tropic of *Cancer*; makes Summer on the north Side of the Equator, and Winter on the ſouth Side thereof.

As the Earth is going from *Capricorn* toward *Aries*, and the Sun appears to move in the Ecliptic from *Cancer* toward *Libra*, the north Pole gradually turns away from the Light, and the ſouth Pole approaches at the ſame rate. Hence,

Summer Solſtice.

Summer on the decline.

Hence, the Days shorten and the Nights lengthen in the northern Hemisphere, as the contrary happens in the southern, till the Earth arrives at *Aries*, and the Sun from thence appears at *Libra* : Then the Circle bounding Light and Darkness again cuts the Earth thro' both its Poles, because the Sun is in Plane of the Equator; which, with all its Parallels will now go equally thro' the Light and the Dark, by the Earth's diurnal Motion ; and consequently the Days and Nights are again *Equal Day and* of an equal length at all Places of the Earth. The *Night.* Sun now sets to the north Pole, having shone half a Year upon it ; and rises to the south Pole, having been as long absent from it; which makes *Autum-* autumnal Equinox to the Inhabitants on the north *nal Equi-* Side of the Equator, and vernal Equinox to those *nox.* on the south Side thereof.

As the Earth goes from *Aries* toward *Cancer*, and the Sun appears to travel from *Libra* toward *Capricorn*; the north Pole gets more and more into the dark Hemisphere below the Cap, and the south Pole at the same rate advances into the Light. In the northern Hemisphere the Days continue to shorten, and the Nights to lengthen as much; till the Earth comes to *Cancer*, when the Sun appears at *Capricorn*; and then all the Space included within the arctic Circle is involv'd in Darkness, as that which is bounded by the antarctic Circle is all in the Light. The Days are now at the shortest on the north Side of the Equator, *Winter* being gradually shorter as the Places are more *Solstice.* remote from it : In the southern Hemisphere the Effect is contrary. It is now Mid-night at the north Pole, whereto the Sun set at his entring *Libra* ; and Mid-day at the south Pole, to which he then rose. The Sun being now vertical to the

Tropic

Tropic of *Capricorn*, makes Winter in the northern, and Summer in the southern Hemisphere.

As the Earth moves from *Cancer* toward *Libra*, the Sun seems to go from *Capricorn* toward *Aries*; and the north Pole gradually approaches toward the Light, as the south Pole recedes from it. The Days now lengthen in the northern Hemisphere, and shorten in the southern, until the Earth has got to the beginning of *Libra*, and the Sun appears at *Aries*; in which Position the Days and Nights are again equally long to all Places of the Earth; which has now finished one annual Revolution, and gone tho' all its variety of Seasons.

Equal Day and Night always at the Equator.

ALTHO' the north Pole in Summer inclines toward the Sun, and the south Pole from it; which makes the Days longer than the Nights in Summer, and reverses the whole Phænomena in Winter; yet in all Positions of the Earth, its Equator is equally enlightned, because it is always equally cut by the Circle bounding Light and Darkness; and therefore to all Places upon it, the Days and Nights are equally long throughout the whole Year.

Sun's rising and setting.

THE rising and setting of the Sun may be found at any Place of the Earth delineated on the small Globe, by turning the Handle till the given Place points toward the Sun, and then setting the Index on the hour-Circle to XII; which done, turn the Handle backward till the Place is just going in below the Cap, and the Index will point out the Time of Sun rising; thence turn it forward till the said Place comes to the eastern Edge of the Cap, and the Index will shew
the

the Time of Sun setting at that Place, any Day of theYear, as denoted by the Pointer on the Ecliptic.

IF you know at what Time, in any Day of the Year, a given fixt Star comes to the Meridian of your Place, you may find the Time of its coming to the same Meridian every other Day of the Year, in the following manner. Turn the Handle till the Pointer on the Ecliptic comes to the Day you want, then observe when the sydereal Index points to the Time of the said Star's coming to the Meridian; stop there, and set the Index on the hour-Circle to the same Time either of the Day, or of the Night; reckoning the 12 on the sydereal Dial Plate to be Mid-night, and the 24 thereon to be Mid-day. This done, fix a bit of Paper on the Wall of the Room, so as it may face your Meridian in the Position it now stands; and let this Paper represent the fixt Star at a great Distance. Then turning the Handle, observe when the sydereal Index *always* comes to the same Time on its Dial Plate, which it continually does when the Plane of your meridian-Semicircle extended, would pass thro' the Star or Paper, and the Index of the hour-Circle then points out the mean Time of the given Star's coming to the Meridian every Day, as shown by the Pointer on the Ecliptic: and it will be seen to come to the Meridian almost four Minutes sooner every Day than it did on the Day before, which in about 15 Days, will make an Hour; and so of Course will be 12 Hours in half a Year. Therefore, any Star about the Equator, which at any particular Hour on a given Day rises in the East, will in half a Year after, set at the same Hour in the West; because in that Time the Earth has gone thro' one half of its annual Circuit; and at the end of another

When any fixt Star comes to the Meridian.

other half Year, it will rife in the Eaft at the fame Hour in which it rofe on that Day Twelve-month before. Hence, let the number of folar Days in any Year be what it will, in the Earth or any other Planet; the number of fydereal Days will be one more.

In this fmall Globe or Earth are four Pin-holes, one in the Equator, one in each Tropic, and one in the Parallel of *London*. In each of thefe Holes put a Pin (having firft taken off the Cap) to reprefent fo many Inhabitants, each ftanding with his Feet toward the Center of the Earth: Then turn the Handle till the Sun by the Pointer appears at *Aries*, when he will be vertical to the Inhabitant on the Equator, who can have no Shadow that Day at Noon. But in *How the* the Forenoon, his Shadow will be projected a-*Earth's* long the Equator Weftward, and in the After-*Inhabi-* noon it will be Eaftward on the Equator, with-*tants caft* out the leaft fenfible Deviation from it, all that *their Sha-* Day; as may be feen by taking off the Sun, and *dows.* putting a bit of Wax Candle in its Place. But as the Pointer on the Ecliptic advances toward *Cancer*, the Shadow will be gradually thrown Southward, as the north Pole inclines more and more toward the Sun; till by the Pointer he appears at *Cancer*, when he will be vertical to the Pin or Inhabitant on the northern Tropic at Mid-day, and the Pin will have no Shadow at that Time; but at all other Times his Shadow will fall on the North fide of the Tropic of *Cancer* whereon he ftands. Turn on, till the Poin-ter is at the beginning of *Libra*, and then the Inhabitant on the Equator will have no Shadow at Noon; but he will have it Weftward in the Forenoon, and Eaftward in the Afternoon as be-fore;

fore; and now for half a Year it will fall on the North fide of the Equator. When the Pointer comes to *Capricorn*, the Sun is vertcial to the fouthern Tropic, whofe Inhabitant will have no Shadow at Noon that Day: But as the Earth travels forward, the Shadow will fall to the Southward of the faid Tropic. Hence, every Year the Sun is twice vertical to the Equator, and once to each Tropic; but never to any Parallel of Latitude, between either of the Tropics and its neareſt Pole. Thus by putting Pins in different parts of the Globe, as one in the middle of each Zone, the *Amphiſcians*, *Periſcians* and *Heteroſcians* may be known by their manner of caſting their Shadows.

As the Earth is carried about the Sun, its progreſſive Motion is ſo much ſlower in the *Earths annual Motion unequal.* Southern half of the Ecliptic than in the Northern, as makes the Sun appear to be eight Days longer in going from the beginning of *Aries*, to the beginning of *Libra*, than it takes to go from thence to *Aries*; by which Means it goes faſter in our Winter as it approaches nearer the Sun, than in Summer as it recedes further from him; for its annual Motion is Excentric; ſo are thoſe of *Venus* and *Mercury* in this Machine. *Quickeſt in our Winter.*

THE Moon goes round the Earth in the Plane of an elliptical Ring, which repreſents her Orbit, making an Angle with the Ecliptic, as the Moon's Orb does in the Heavens. Therefore the Moon will be ſometimes on the north Side, and ſometimes on the ſouth Side of the Ecliptic, which is called her north and ſouth Latitudes; the Degrees and Parts whereof are engrav'd from each Node, to the higheſt and loweſt parts of her Orbit; which is 5 Degrees 18 Minutes on each ſide of the Ecliptic: *Phænomena of the Moon.* *Her different Latitudes.*

D

tic: and where the reckoning ends, is marked N L for North Latitude; and S L. for South Latitude. *Her Nodes* The two Nodes ly in the Plane of the Ecliptic, in thofe Parts of the Moon's Orbit where the Wires that fupport it are fixt. *That* from which the Moon begins to afcend Northward above the Ecliptic, is called the Afcending, or north Node; as the oppofite *one* from which the Moon de-fcends Southward below the Ecliptic, is called the Defcending or fouth Node. A right Line drawn from the one to the other, would pafs *Line of* thro' the Earth's Centre, and be called *the Line. the Nodes. of the Nodes.* They always keep oppofite to one another, and move backward thro' all the twelve Signs of the Ecliptic in almoft nineteen Years; and on each fide of them both is engrav'd a fmall *Sun* 18 Degrees, and a fmall *Moon* 12 De-*Limits of* grees, diftant from them: Thefe are the Limits *the Eclip-* of Eclipfes, the firft of the Sun, and the other *fes.* of the Moon.

I_F_ the Moon's Orb lay altogether in the Plane of the Ecliptic, there would be an Eclipfe of the Sun (as it is very improperly called) at every new Moon, becaufe the Moon's Shadow then paffing over fome parts of the Earth, would de-*The Sun* prive them of the Sun's Light. But becaufe the *not Eclip-* Sun is a great luminous Body, and the Moon a *fed at eve-* fmall opake one, her Shadow will be Conical; *ryChange.* and can only cover a fmall part of the Earth at once; and therefore there would be many fuch Eclipfes invifible tho' at Noon-Day, to a great *Nor the* many Places of the Earth. At every full Moon, *Moon at* fhe would pafs thro' the Earth's Shadow, which *everyFull.* would be broad enough to cover her, if her Dia-meter was three Times as large as it really is: And fo fhe would undergo a *real* Eclipfe; Total

to

to all the Earth's Inhabitants who would have the oppportunity of feeing it. But becaufe the Sun and Earth are always in the Plane of the Ecliptic, and the Moon's Orb is inclined to it, and cuts it only in the Nodes; 'tis plain there can be no Eclipfes of the Sun or Moon, but when the Line of the Nodes either paffes thro' or nearly by the Sun, at the Time of New or Full Moon : And from the Time that this happens till it does fo again, is about 173 Days or near half a Year; fave what allowance is to be made of 18 Days or Degrees on either fide of the Nodes, within which the Sun may be Eclipfed ; and of 12 Degrees, within which the Moon may fuffer an Eclipfe; as is fhown by the Limits above mentioned.

Becaufe her Orb lyes not in the Plane of the Ecliptic.

When Eclipfes may happen.

As the Moon goes round the Earth, fhe ftill keeps the fame Face or Side toward it; the reafon whereof is, that fhe turns round her Axis exactly in the Time that fhe revolves round the Earth ; which (as was mentioned before) is in 27 Days and about 8 Hours; and that will be the Length of her fydereal Day; for then fhe will have fhown her felf all round to any fixt Star near the Ecliptic, which is juft as good a demonftration of her turning round an Axis within her own Body, as the Earth's fhewing it felf round to a fixt Star in 23 Hours 56 Minutes is of its turning round its own Axis in that Time. But her folar or natural Day is from one Conjunction to another, in which Time fhe fhews her felf all round to the Sun; namely in 29 Days and an half of our terreftrial Time : And this we may fee by the Orrery in the following manner.

Why the Moon ftill keeps the fame fide toward the Earth.

Her folar Day equal to a lunar Month.

TURN

Turn the Handle till the Moon is in oppofition to the Sun, that is, when all the half of her next the Earth is without the black Cap, which fhews her *Phafes* by dividing the enlightned, from the darkned Hemifphere; and then fhe will appear with a full Orb as feen from the Earth. In the middle of this Orb, Face, or Difc (call it which you pleafe) is a fmall black Spot reprefenting an Inhabitant, who at that Time has the Sun in his Meridian. In the Plane of this Meridian, fix a bit of Paper at a diftance on the Wall, which may be done by ftretching a Thread from the Moon over the Earth and Sun to the Wall, and pinning the Paper there; which will reprefent a fixt Star in the Meridian with the Sun. This done, turn the Handle, and the Spot will turn away both from the Sun and Star, toward the eaftern Edge of the Cap; and the Sun as feen from the Spot will appear to turn lower and lower, till the Moon comes to her third Quarter, and then the Sun will fet to the Spot as it goes in below the Cap, when one half of the Moon?s Side next the Earth difappears, becaufe it is hid in the Dark. Turn on till the Moon comes to her Conjunction, when all the fide of her next the Earth goes in below the Cap; then fhe difappears quite to it, being the Time of New Moon; and the Spot or Inhabitant is in the middle of the dark Hemifphere, and confequently it is Mid-night to him: But he will fee the whole enlightned fide of the Earth, appearing full and fhining ftrongly upon him; becaufe to him it is then in Oppofition to the Sun. If the Moon at that Time is in or near any of her Nodes, he will fee a Spot travelling over the Earth, which is the Moon's fhadow, and the Inhabitants

Moon's Phafes.

habitants of the Earth under it will then have an Eclipse of the Sun. Turn on, and when the Moon comes to her first Quarter, the Spot or Inhabitant on her will be just coming into the Light, and the Sun will appear as rising to him: The side of the Moon next the Earth being just half in the Light and half in the Dark at that Time. Continue turning, and the Spot will advance more and more into the Light, as the Sun appears to rise higher and higher to it : But if you now carefully observe the Spot, you'll see it point toward the Paper or Star, two Days (or turns of the Handle) and four Hours, before the Moon comes to her next Opposition, and here her sydereal Day is finished: But the Spot will not point toward the Sun until you turn the Handle 2 $\frac{1}{6}$ Times round ; and then the Moon will be Full, or in her Opposition ; and the Spot or Inhabitant will have the Sun again in his Meridian, which will compleat his solar Day ; and the Earth being then between him and the Sun, becomes invisible to him. If the Moon be at that Time near any of her Nodes, the Inhabitants on her will have an Eclipse of the Sun, because the Earth's Shadow will fall upon the Moon, and cause her to be Eclipsed as seen from the Earth. So a lunar Eclipse to the Earth is a solar Eclipse to the Moon, and a New Moon answers to a full Earth ; as a Full Moon does to a new Earth. When the Moon is in her first Quarter, she sees the Earth in its third Quarter, and *vice versâ*.

How a solar Eclipse on Earth appears to the Moon.

A lunar Eclipse to the Earth is a solar one to the Moon.

THE Difference between the Moon's sydereal and solar Day (or between Her periodical and synodical Revolution) arises from the Earth's going forward in the Ecliptic almost a whole Sign, while the Moon is going round the Earth in her

Orbit ;

Orbit ; and therefore fhe never finds the Sun where fhe left Him at the laft Conjunction, but muft travel forward 28⅔ Degrees from that Place to overtake him at the next. This may be very well underftood by the Hour and Minute-hands of a Watch, which being together, or in Conjunction, fuppofe at XII on the Dial-plate : both Hands go forward like the Sun and Moon, tho' the Minute-hand goes fomewhat too flow to reprefent the Motion of the Moon, with regard to the Sun's Motion as reprefented by the Hour-hand ; becaufe the Minute-hand makes but 11 Conjunctions with the Hour-hand in the Time that it moves round ; whereas the Moon makes 12 Conjunctions and ⅓ more with the Sun in the Time that he apparently moves once round the Ecliptic. When the Minute-hand goes round from XII to XII again, it finds not the Hour-hand there ; for it has gone in that Time to I and will be a little paft I, when the Minute-hand overtakes it at its next Conjunction. Thus, the Motion of the Minute-hand round the Dial-plate, from any Place thereof to the fame Place again, is its Periodical Revolution ; and from the Hour-hand to the Hour-hand again, is its fynodical Revolution.

A reprefentation of the Moon's periodical and fynodical Revolution.

ALTHO' the Moon puts on different Phafes as feen from the Earth, yet to an Eye placed in the Sun fhe would always appear Full ; as is plainly fhown by her Cap, which ftill Faces the Sun, as it fhews it felf all round to the Earth, once in every Lunation. The Side of the Moon that ftill keeps toward the Earth is engraven to diftinguifh it from the other ; and to make her turning round her Axis the more vifible by Means of the Cap, which fhows her Phafes as they appear to the Earth, and turns round its own Axis only once in a Year.

The Moon always Full to the Sun.

Yet

Yet the fame fide of the Moon is not fo exactly
kept toward the Earth (tho' fhe turns uniformly
round her Axis) but that twice in every Lunation
it is turned a little away; and twice brought back
again. This is the Effect of two Caufes, the one *Her Li-*
whereof is the Elliptical Figure of the Moon's Or- *bration.*
bit, the other is her rifing above, and falling be-
low the Ecliptic as fhe goes round the Earth in
herOrbit, to which herAxis is not perpendicular.
By thefe Means fhe acquires that nodding Motion
called her *Libration*, which in thisOrreryis very
vifible. The Moon is moft enlightned at her Con-
junction, being then neareft the Sun, tho' fhe
difappears to the Earth at that Time ; and is
leaft enlightned at her Oppofition becaufe fhe is
then furtheft from the Sun, tho' fhe then appears
moft enlightned to the Earth, becaufe fhe fhines *The Earth*
with a Full Orb or Difc upon it at that Time. *a goodDi-*
ALTHO' we have no Opportunity of meafuring *al to the*
Time by the Lunar Spots, becaufe fhe ftill keeps *Moon.*
the fame Side fo nearly obverted to theEarth; yet
the Earth may be a very good Dial to the Moon's
Inhabitants who have it in their view : For by
the diverfity of its *Phafes*, by the approach of the
Sun or Stars toward it, by the Name of the Pole
that it fhews,and by the fwiftMotion of its Spots,
fuch as Seas, fnowy Places, Iflands, high Moun-
tains, &c. It divides the Day and the Night
(which is equal to 29 ½ naturalDays on the Earth)
into a fufficient Number of Parts ; and fo will be
of good ufe in meafuring Time to the lunar In-
habitants on the Side next the Earth : But can be
of no ufe to thofe on the other Side, becaufe they
never fee it. Here it may be obferved, that in
the Courfe of a Lunation, the Earth as feen from
theMoon appears to turn only twenty eight times
and

A turn of the Earth round its Axis loſt to the Moon in every Lunation.

and an half round its Axis; for ſhe loſes the appearance of one turn by going round the Earth, from the Sun to the Sun again; becauſe her Motion round the Earth, and its turning round its Axis, are both performed the ſame Way, namely from Weſt to Eaſt.

To ſhew the mean Times of all the New and Full Moons, and Eclipſes both of the Sun and Moon, with the Conjunctions, Oppoſitions, ſtationary Places, and retrograde Motions of Venus *and* Mercury, *for Times paſt or to come; the Orrery may be rectified in the following Manner, to any given Time.*

How the Orrery is to be rectified for any Time.

TURN the Handle till the Pointer on theEcliptic comes to the given Day; which for conveniency's ſake may be the Day of any particular new Moon; ſtop there, and ſet the Moon by yourHand directly between the Sun and Earth, bating what allowance is to be made for the Obliquity of her Orbit, wherein at that Time ſhe may chance to be above or below the Plane of the Ecliptic, in which the Earth always moves; then ſet the Index that ſhews her Age to the $\frac{1}{2}$ Day on the Circle of $29\frac{1}{2}$ equal Parts, and it will point toward the Sun. Look into your Ephemeris for the Moon's Latitude on that Day, and as it is North or South Aſcending or Deſcending, ſet the Moon's Orbit ſo as the Degree or part of a Degree of Latitude may be cloſe by the Moon, in a Plane cutting the Centers of the Earth, Moon and Sun. This done, look for the Heliocentric Places of *Venus* and *Mercury* in the Ephemeris, and laying a Thread from the Sun, firſt over the Place of *Venus*, and then over the Place of *Mercury*, in the Ecliptic; firſt ſet *Venus*, and then *Mercury*, to the Thread at their reſpective Places, and the Machine will be rectified.

N. B.

N. B. In setting the Moon, or her Orbit, or the Planets or Indexes by Hand; you'll be the more exact if you set them backward, or contrary to the way they move by turning the Handle; because there are no Wheel-Machines made, but what must have some shake in the Teeth of the Wheels. *A Caution in doing it.*

THE Orrery thus rectified, will by turning the Handle backward for Time past, or forward for Time to come, shew the mean Times of all the new and full Moons and Eclipses, &c. as abovesaid; with the Sun's Place and Moon's Latitude every Day in the Year. For, when the Moon is in Conjunction with the Sun, or Opposite thereto, the Pointer on the Ecliptic will shew the Day of *that* new or full Moon: And *New and Full Moon.* when the Moon at her Conjunction comes between the little *Sun* on her Orbit and any of her Nodes, the Sun will appear to be Eclipsed; and *Sun Eclipsed.* by the Position of the Earth and Moon, you can judge whether the Moon's Shadow will fall on the Equator, or on the North or South side thereof. When the Moon at her Opposition comes between the little *Moon* and any of the Nodes in *Moon Eclipsed.* her Orbit, there will be an Eclipse of the Moon on that Day, as shown by the Pointer; and you may know whether it will be Total or Partial: For if the Moon's Latitude be less than half a Degree, North or South; She will be totally Eclipsed: Otherwise the Eclipse will only be partial at that Time. Thus you may see the true Number of Eclipses in any Year, both of the Sun and Moon, by these Limits; which would be *The true Number* impossible to be done without them, in the usual *of Eclipses* way of putting a Lamp instead of the Sun; *shown.* even tho' the Operator should put on a smaller

E   Earth

Earth and Moon than thofe that are ufed at other Times; unlefs the Machine be made very large, and the Moon's Orbit therein be much inclin'd, fo as to make a great Angle with the Ecliptic: The laft of which is deftroying one Truth too far to explain another. To make this Inclination the more vifible, I have made it double to what the Moon's Orbit is inclin'd to the Ecliptic in the Heavens; and have made the Moon's diftance from the Earth as great as in moft Orreries that take in all the Planets. Yet tho' I had made the Earth no bigger than a Pea, and the Moon but a third part thereof in Diameter; I fhould ftill have been obliged to make the Angle of Inclination much greater, to let the Moon's Shadow pafs freely by the Earth without touching it at new Moon, when fhe is only eighteen Degrees from any of her Nodes: Or that at full Moon fhe fhould efcape being touched by the Earth's Shadow at twelve Degrees diftance; as every one will find upon Tryal. And this is the reafon why I make my Orrery fhew the true Number of Eclipfes, by fetting their Limits on the Moon's Orbit; without taking the trouble of putting on any other Earth and Moon than what are ufed for other purpofes: efpecially feeing *that* could not be done without fomeTrouble on account of the fydereal Dial-plate: And it is eafy to conceive how, if thefe Bodies were fmall enough in proportion to their diftance from one another, the Shadow of either of them might pafs by the other without touching it, at its proper diftance from the Node.

By their Limits on the Moon's Orbit.

THERE is a Wire with a fmall Knob at one end thereof, and a Hole in the other to be put upon a Stem proceeding from a Crefcent (whofe ufes fhall be

be fhown afterwards) perpendicularly above the Earth; the Hole being wide enough to let the Wire be convertible round the Stem. Having put it on there, keep it with your left Hand over *Venus* or *Mercury*; while with your right, you turn them round the Sun by the Handle. In doing this, obferve the Knob, for it will reprefent the Motions of *Venus* or *Mercury* as feen from the Earth, with refpect to the fixt Stars; and it will fometimes go forward, fometimes backward, and at other times it will ftand ftill, on the Ecliptic. This clearly fhows why the Planets, by ftill moving forward in their Orbs, appear from the Earth fometimes Direct, fometimes Retrograde, and at other times Stationary among the fixt Stars; and the Pointer on the Ecliptic will fhew the Times of all thefe different Appearances. A thread laid from the Sun, over *Venus*, or *Mercury*, will fhew its *Heliocentric* Place on the Ecliptic, at any Time; as the Wire laid over either of thefe Planets, from the Earth, will fhew its *Geocentric* Place on the Ecliptic at any time alfo; as indicated by the Pointer. And to know what the Moon's Latitude or Declination from the Ecliptic is at any Time, turn the Handle till the Pointer comes to the given Time in any Month, and you'll fee the Moon's Latitude by the Place where fhe then is, in her Orbit.

Direct, Stationary and Retrograde Appearances of Venus and Mercury.

Their Heliocentric and Geocentric Places.

Moon's Latitude.

THERE are two Semicircles croffing one another as right Angles, and fixt to an elliptical Ring, from which proceeds a forked piece to go over the Moon, when the faid Ring and Semicircles are like a Cap put upon the Earth, having firft taken off the black Cap which is ufed at other Times: In turning the Handle, this will be fo led about

the

Motion of the Tides.

the Earth by the Moon, as to shew the mean Motion of the Tides, how they would roll if the Earth was all covered with Water, so as no Eminencies of Land might hinder the Sphæroid of Water from following the Moon; whereby they roll from East to West contrary both to the diurnal Motion of the Earth, and the Moon's Motion round it; because when any Place of the Earth has the Moon in its Meridian, it moves so quickly Eastward from the Moon as to leave her on the West side: But in the Time that the Earth turns round its Axis from the Sun to the Sun again, the Moon makes so much of a Revolution round the Earth, as makes the Tide happen about $\frac{3}{4}$ of an Hour later every Day at any given Place, than on the Day preceeding. Because of the Inclination of the Earth's Axis, and Obliquity of the Moon's Orbit, the Tides shift over the Equator and Tropics; being high there abouts, and diminishing gradually toward the Poles, where they are scarce perceptible; as is shown by the Semi-circle coloured green, whose Plane produc'd would pass thro' the Moon; it being broadest under the Moon, where the Waters are most attracted; and turns gradually narrower to the Place where the other Semi-circle intersects it, where there is no attraction to raise the Waters; and may be called one of the Poles, or ends of the Axis whereon the Tides turn: The other Pole is suppos'd opposite to this; and it is curious to see how these Poles shift over the Poles and polar Circles of the Earth, as the high Tides shift over the Equator and Tropics.

THE other Semi-circle is white, and being all equally broad, serves for a lunar Horizon, or Boundary for all Places of the Earth to which

the

Why they happen later every Day than on the preceeding.

None about the Poles.

Lunar Horizon.

the Moon is visible at any Time ; and shews the Moon's rising and setting, as affected by her different Latitudes at all Times. If over this, you put the Crescent (above mentioned) so as its Plane may pass thro' the Earth's Centre, by fixing it to the Stem that held the Earth's Cap, it will still Face the Sun, and so become a solar Horizon, or Circle bounding Light and Darkness; *Solar* shewing how long the Moon rises or sets before *Horizon.* or after the Sun, every Day of her Age, by the Index on the Hour-Circle, and that on the Circle of 29 ½ equal parts. For, when any Place of the Earth is just coming out from below the solar Horizon, the Sun rises to that Place; and sets to it, as it goes in below the other Edge of the same Horizon or Crescent. The like is to be observed with respect to the Moon's rising and *Moon's* setting, when the same Place of the Earth comes *rising and* out from below, and goes in under the lunar Ho- *setting.* rizon; the Times whereof will be shown every Day by the Index on the Hour-Circle. At new Moon, if she has no Latitude, the two Horizons coinciding, will shew that the Sun and Moon rise and set about the same time; but at the first Quarter, these Horizons crossing one another at right Angles, shew the Moon to rise about Midday, pass over the Meridian about six in the Evening, and set about Mid-night. At the full Moon, the Face of the solar Horizon and back of the lunar One coincide ; whereby the Moon appears to rise at Sun-setting, to pass over the Meridian at Mid-night; and to set at Sun-rising; having shone all Night upon the Earth. At the third Quarter, the two Horizons crossing one another again at right Angles, but the lunar Horizon facing the contrary way to what it did at the

the firſt Quarter, ſhew that the Moon riſes at
Mid-night, paſſes over the Meridian about ſix
in the Morning, and ſets about Mid-day. This
is what would happen if the Moon had no Lati-
tude, or if her Orbit lay all the while in the
Plane of the Ecliptic ; but as it does not, her
riſing and ſetting will be very irregular on that
account, the Varieties whereof are plainly ſhown
by this new, tho' ſmall Apparatus.

The juſtneſs of the Planetary Motions in this Or-
rery may be ſeen in the following manner.

TURN the Handle till the Pointer comes to the
beginning of *Aries*, obſerving at that Time
when the Meridian of your Place is turned to-
ward the Sun ; then ſet the Index on the Hour-
Circle to XII at Noon, and the Index on the ſy-
dereal-Dial-Plate to 24 ; then turn the Handle,
and as the Earth proceeds forward in the Ecliptic,
you'll ſee the ſydereal Index on its Dial-Plate
gaining Time of the ſolar Index on the Hour-
Circle ; which will always point to the ſame XII
when your Meridian turns to the Sun : But in
a Quarter of a Year, the ſydereal Index will be
ſix Hours before the ſolar One ; in half a Year,
12 Hours; in three Quarters of a Year, 18
Hours; and in a whole Year, 24 Hours or a
whole Circle; which it will have gained of the
ſolar Index in 365 Days, or ſo many turns of the
Handle. Note upon the Ecliptic, the Day of
any new Moon, and fix a bit of Paper over againſt
her on the Wall, as ſeen from the Earth ; then
turn the Handle 27 ½ times round, which will
bring the Moon round the Earth, ſo as to point
from it to the bit of Paper again ; but to bring
her round from the Sun to the Sun again, requires
29 ½ turns; and the Pointer on the Ecliptic
will

will have paft over fo many divifions, to the Day
of the next new Moon : becaufe as every turn of
the Handle brings any meridian-Semicircle up-
on the Earth quite round from the Sun to the
Sun again, and carries the folar Index round its
hour-Circle; fo it advances the Pointer on the
Ecliptic one Day forward among the Months.
Turn on till twelve Lunations are accomplifh-
ed, which will happen eleven Days before the
Pointer comes again to the fame Day on the E-
cliptic from which you began to compute :
And it is commonly known that twelve Luna-
tions come eleven Days fhort of a folar Year,
which is the Foundation of the Epact.   Turn the
Handle till the Line of the Nodes, if produc'd
would pafs thro' the Sun's Centre; then note
the Place of the Pointer among the Degrees of
the Ecliptic, and turn the Handle till the fame
Node, in the Line of Nodes, comes between
the Centre of the Earth and of the Sun again ;
ftop there, and you'll fee the Pointer cut the E-
cliptic almoft 19 Degrees fhort of what it did
before ; then turn the Handle, till the Pointer
is carried forward *that* 19 Degrees (in which
Time the Nodes are ftill moving backward) and
the Line of the Nodes will be gone 19 ½ Degrees
backward ; which is their Retrogradation every
Year. This fhifting backward or contrary to
the order of Signs, is the reafon why the Eclip-
fes happen every Year fooner than they did on
the Year before ; whereby they are gradually
remov'd from the Confequent, toward the Ante-
cedent Signs.   If you put a bit of Paper or a
Patch on the Sun over againft any part of the
Ecliptic, fo as to be juft coming in fight of the
Earth ; and then turn the Handle 25 ½ times
round,

round, the Sun will have carried the Paper or Patch quite round, fo as to point at the fame Place of the Ecliptic again; but it will require two turns more to bring it in view from the Earth again, becaufe the Earth has been going forward in the Ecliptic while the Sun was turning round his Axis.

If you obferve any meridian-Semicircle of *Venus* that looks toward the Sun, and turn the Handle 24 ⅓ Times round, the fame Semi-circle will again be turned toward the Sun, but he will not be vertical to the fame Place as before. If you firft fet *Venus*, and *Mercury* by hand between the Earth and the Sun; and note their Places in the Ecliptic, by laying a Thread from it, over them to the Sun, and then turn the Handle 88 times round, *Mercury* will be gone quite round fo as to point from the Sun toward the fame Place of the Ecliptic again. But to bring him in a right Line between the Earth and Sun again, or to his next inferior Conjunction, will require 28 turns more; in all, 116 Days. All this time, *Venus* has gone little more than half round the Ecliptic; and therefore you muft turn the Handle 109 times more round which will compleat her Revolution; equal to 225 Days in round Numbers. But to bring her to her next inferior Conjunction, you muft turn the Handle 258 times more round; which added to the former 225, makes 583 turns, equal to a Year and 218 Days.

The Motions of *Venus* and *Mercury* come nearer the Truth in this Machine, than what is here mentioned; but if they did not, they would ftill be near enough, when they are fo quickly fhown as by turning the Handle, which may be 365 times

times done in lefs than a quarter of an Hour ; and in this quick Way of Inftruction, the Fractional Parts of Hours and Minutes in the annual Revolutions, cannot be obferved ; and confequently muft be loft as to Senfe.

I almoft believe it is in vain for any Man to pretend to make the Planetary Motions fo exact in a Machine as for ever to agree with their Originals in the Heavens : But if I was to fit an Orrery to the true Motions of a well going Clock, I would at a fmall additional Charge make it fo, as when moved by the Clock, to perform the Earth's annual Motion in 365 Days 5 Hours 48 Minutes and 57 Seconds : Its Motion round its Axis (*or fydereal Day*) in 23 Hours 56 Minutes 4 Seconds and 6 Thirds : Its folar or natural Days in 24 Hours. The Moon's Motion round the Earth in her Orbit in 27 Days 7 Hours and 43 Minutes ; from new Moon to new Moon again, in 29 Days 12 Hours and 45 Minutes. *Venus's* annual Motion in 224 Days 17 Hours ; her diurnal Motion in 24 Days 8 Hours. *Mercury's* annual Motion in 87 Days 23 Hours : and the Sun's Motion round his Axis in 25 Days 6 Hours. How near the truth thefe are, I leave to the Judgment of thofe who have read aftronomical Accounts of the celeftial Motions.

When fuch a Machine is turned by Clock-work, it is inftructive only in a flow tedious Way to thofe who can have daily recourfe to it ; and fuch remarkable Things, as Eclipfes of the Sun and Moon, or the Conjunctions, Oppofitions, &c. of the Planets, cannot well be predicted by it for any confiderable times before they happen. But if it be made fo as that it can be difengaged from

the

the Clock, and turned by Hand at pleasure, they may; tho' there will be some Trouble in putting it to the Clock again, because the Planets must be then set to the same Places, where they would have been by the Clock's Motion; which I take to be the Reason why so few Orreries are made to be turned any other Way than by the Hand, *that* being the most instructive Way of shewing the planatary Motions by them.

Every Reader is requested to Pardon the badness of the Printer's Types, and to correct these:

ERRATA.

Page 14, L. 13, *for* Venus', *r.* Venus's; and in the Margin *for* Venu's, *r.* Venus's; P. 16, L. 1, and 2, *for* Wire-passing, *r.* Wire passing; P. 20, L. 12, *dele* . after Sun.

FINIS

The Reader is defired to correct the following
Errors of the Prefs.

Page 6, Line 15, *for* and Friction, *read* and lefs
Friction. P. 14, L. 13, *for* Venus', *read* Venus's; and
in the Margin, *for* Venu's, *read* Venus's. P. 16, L. 1.
and 2, *for* Wire-pafing, *read* Wire paffing. P. 18, L.
22, *for* Earth, *read* Earth's. P. 20, L. 12, *for* Sun. as
read Sun, as. P. 25, in the firft Note in the Margin, *for*
Earths, *read* Earth's. P. 42, L. 9, *for* planatary, *read*
planetary.